

## **Weather Information Communications (WINCOMM) Project: Dissemination of Weather Information for the Reduction of Aviation Weather-Related Accident Causal Factors**

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### **Abstract**

The Weather Information Communications (WINCOMM) Project at the NASA Glenn Research Center is an element of the Weather Accident Prevention (WxAP) Project within NASA's Aviation Safety and Security Program (AvSSP). The goal of WxAP is to develop enabling technologies, which if implemented, will reduce weather-related accident causal factors and turbulence-related injuries by the year 2007. WxAP's efforts include; increasing airborne meteorological sensing that improves weather forecasting accuracy, maximizing data link capacities for dissemination of cockpit weather products, and providing on-board turbulence detections and warnings. WINCOMM's goal, as an element of WxAP, is the development of advanced communications and information technologies enabling the high quality and timely dissemination of strategic weather information between the flight deck and ground users. In addition WINCOMM is responsible for the transfer of tactical turbulence hazard information between relevant aircrafts. WINCOMM is focused on; the definition of weather information communications requirements, assessments of current communications infrastructure, the application and/or development of communications systems addressing technology shortfalls and gaps preventing use and/or implementation

Advanced weather communication data links and networks are being developed to achieve these WINCOMM goals. Airborne atmospheric sensors and Electronic Pilot Reports (EPIREPS) of tactical turbulence hazard information require; on-board networks for the processing and display of own-ship information, air to air data links for hazard awareness from other relevant aircraft, and air to ground data links for the dissemination and formatting of weather data to the data collection centers. This is required to improve both the weather forecasts and products. Ground networks/stations must also provide ground to air data link capabilities enabling the efficient dissemination of weather products and warnings to the cockpit, increasing the situational awareness of pilots and alerting them to potential hazards during the en-route phase of flight. This must be done while not impeding other more critical traffic on the links.

The overall development challenge to WINCOMM is the diverse airborne communications platforms for General Aviation, Business Jets, and Commercial Transport/Cargo Aircraft. This challenge is not limited exclusively to physical attributes but includes considerations of policy including future direction of policies, current/planned equipment, real estate availability and weight augmentation restrictions. The specific challenges to WINCOMM are; the establishment of weather information requirements, cost reduction of the data link for aviation weather, and integration of solutions into the current/future NAS structure.

This report will discuss how WINCOMM is developing advanced communications and information technologies enabling the high quality and timely dissemination of strategic weather

information between the flight deck and ground users, as well as the dissemination of tactical turbulence hazard information between relevant aircraft. Present data link requirements for the dissemination of weather products are being addressed through the utilization and leveraging of existing aviation data links through a multi-use and/or multiple data link solution., Innovative use or enhancement of this existing equipage, as well as influencing future use and/or design of these data links is the approach being pursued. The report summarizes the weather dissemination communications architectures for General Aviation/Regional, Commercial Transport, and International/Oceanic operation scenarios that have been selected for flight evaluation as well as the future looking advanced data link research and development being performed.

## **Introduction**

Early success and stimulation of the market by WxAP and WINCOMM providing weather information to pilots have resulted in first generation systems being commercially available today. The significance of these systems in the ongoing process of weather dissemination research and development is significant and should be applauded. It must be noted that these impressive milestone accomplishments though significant are not the end goal/state. These systems are predominantly broadcast systems, broadcasting the information to the cockpit from the ground via satellite or ground stations. Due to the one way nature of these links, they fail to support dynamic pilot requests of weather products or information beyond the prearranged suite. In addition, direct transfer of sensor and/or hazard information between aircraft, air to air, is not supported by these implementations. Weather dissemination in first generation systems within the aviation community provide limited bandwidth restricting product sets to provide reasonable latencies. Currently available cockpit data links, if combined, would fail to realize the capability an average user would expect over a 56kbps ground modem. This makes providing capabilities comparable to mobile users to aviation neither light nor straightforward.

The methodical process of selecting aviation datalinks to demonstrate dissemination of weather information included the following:

- Weather Dissemination Concept of Operations
- Communications Datalink Requirements
- Selection of Candidate Architectures
- Current and Planned Equipage
- Current Use Restrictions
- Policies Affecting Future Datalinks
- Datalink Cost
- Modeling and Simulation
- Flight Validations

This report describes the aviation data link architectures selected for demonstration and/or validation for the dissemination of weather information in a combination of laboratory and relevant flight environments. The validations will demonstrate the ability of the selected data links to disseminate weather information during the en-route phase of flight from ground-based weather information providers to the flight deck (ground to air), from airborne meteorological sensors to ground users (air to ground), and weather/turbulence hazard information between relevant aircraft (air to air). Ground networking includes; routing of airborne sensed weather

data from ground stations to data collection centers, weather information from providers to ground stations for transmission to aircraft. Information within this report includes; selected data links, disseminated weather information, laboratory configurations and flight configurations.

WINCOMM has targeted three distinct operational architectures for the development and validation of weather information dissemination based on aircraft class and operational airspace. The WINCOMM organization is aligned with the four major deliverable products which are:

- National Capability for Regional/General Aviation (GA) Weather Dissemination
- National Capability for Commercial Transport Weather Dissemination
- Global Capability for Weather Dissemination
- Advanced Data Link Technology Candidates for Weather Dissemination

The role and focus of WINCOMM is on the identification and subsequent validation of any required modifications to enable weather information dissemination over these data links. It is not the intent or responsibility of WINCOMM to perform characterization of these existing data links as any activity of this nature would duplicate the efforts of the data link creators and equipment manufacturers. Modifications will not be made to the basic message structure or physical layer of the data link, insuring that other (non-weather related) traffic remains intact and unaffected by the inclusion of weather information.

WINCOMM is not responsible for sensor or display development or testing. However, actual or representative sensors and displays are required to validate weather information communications. Emulations are used to accomplish these objectives for two basic reasons. First, actual hardware requiring modifications may be delayed in manufacturing or within other display or sensor development projects. The second reason for emulation is to insure that a representative data set utilizing an actual flight profile is used and sent over the data link, especially for the laboratory environment. Finally, the adequacy or effectiveness of the weather information communicated is not addressed by WINCOMM.

Validation in laboratory and relevant flight environment of all but advanced data link technology candidates must occur before the project scheduled completion of September, 2005. However, the option exists should any advanced data link technology reach an acceptable level of maturity suitable for lab or flight validation.

Laboratory and selected flight validation/demonstration of weather dissemination technologies are aligned with the product deliverables. Validation of data links are separated into the following three en-route flight scenarios:

- Regional / General Aviation
- Commercial Transport
- International / Oceanic

The data link validation goals are as follows:

- Perform Successful Transmission and Reception of Weather Information
- Show that Weather Information flow does not impact "Normal" Traffic
- Demonstrate the Feasibility of an Operational Implementation
- Lay the Foundation for Future Data Link Development

The validation of data links is accomplished through partnerships between WINCOMM, FAA, industry, and academia. WINCOMM coordinates with the Aviation Weather Information (AWIN) and Turbulence Prediction and Warning Systems (TPAWS) project elements, also within the WxAP Project, to assure mutual goals and benefits are realized.

### **Regional / General Aviation**

The specific goal of the Regional/GA task area is to develop a weather dissemination capability for general aviation and regional aircraft within a national network that includes:

- On-board sensor and telemetry information to ground users and between aircraft. (air-ground, air-air)
- Broadcast of graphical weather products to the cockpit. (ground-air)

The objective of the Regional/GA task area is to demonstrate a path to implementation for the following value added objectives:

- Cockpit display of own ship sensor information.
- Broadcast of data from an onboard sensor to other aircraft and ground users.
- Receive and display information from other airborne sensors.
- Receive and display ground-air Flight Information Service Broadcast (FIS-B) weather products.

The architecture selected for development of a Regional/GA weather dissemination capability uses the Universal Access Transceiver (UAT) system under development for the FAA. UAT will be utilized to satisfy requirements for ground to air broadcast of weather information, air to ground delivery of atmospheric data from airborne sensors, and air to air reporting of weather hazard information to aircraft within coverage of the transmitting aircraft.

- Weather information from an appropriate weather service provider is routed to the Ground Based Servers (GBSs) via the UAT network hub located at the FAA Tech Center in Atlantic City, New Jersey where it is then broadcast by the Ground Based Terminals (GBTs) to aircraft. Airborne sensor data is processed for display onboard the aircraft and broadcast to other aircraft within range for possible hazard alerts/warnings. The GBTs will also receive these messages, providing required formatting and routing for successful delivery to the appropriate data collection center.

### **Commercial Transport**

The specific goal of the Commercial Transport task area is to develop a weather dissemination capability for commercial transport aircraft within a national network that includes:

- On-board sensed turbulence information to ground users and between aircraft. (air-ground, air-air)
- Broadcast graphical weather products to the pilot. (ground-air)

The objective of the Commercial Transport task area is to demonstrate a path to implementation for the following value added objectives:

- Dissemination of data from own ship turbulence events to other aircraft and ground users.
- Receive, process and deliver valid turbulence warnings to the cockpit from other equipped aircraft.
- Receive and display Flight Information Service Broadcast (FIS-B) ground-air weather products.

The architecture selected for development of a Commercial Transport weather dissemination capability uses the FAA Very High Frequency (VHF) Data Link Mode 3 (VDLM3) and 1090 Extended Squitter (ES) Automatic Dependent Surveillance Broadcast (ADS-B) data links. VDLM3 will be utilized to satisfy requirements for ground to air broadcast of weather information and air to ground reporting of turbulence hazards. VDLM3 will also accommodate pilot requests for specific weather information not included in the basic broadcast (ground to air weather information). The VDLM3 ground network will provide routing on the ground of turbulence data to the appropriate data collection center. 1090ES will satisfy the requirements for the air to air delivery of Electronic Pilot Reports (EPIREPS) of turbulence alerts and warnings to other aircraft within coverage.

Weather information from an appropriate weather service provider is routed to the VDLM3 Ground Stations where it is then broadcast to the aircraft for display in the cockpit. Pilot requests from the aircraft for specific weather information not included in the basic broadcast set is routed to the weather service provider and delivered to the aircraft via an augmented broadcast message.

- Airborne turbulence data is broadcast via 1090ES to all aircraft in the vicinity as limited by the radio frequency (RF) range determined by the antenna configuration and transmitted power of the sending aircraft and the antenna configuration receiver sensitivity of the other aircraft. Turbulence data is also sent to the ground via the VDLM3 air to ground data link and routed to the appropriate data collection center.

## **International / Oceanic**

The specific goal of the International/Oceanic task area is to develop a global weather dissemination capability for commercial transport aircraft that includes:

- On-board sensed turbulence information to ground users and between aircraft. (air-ground, air-ground-air)
- Broadcast graphical weather products to the pilot. (ground-air)

The objective of the International/Oceanic task area is to demonstrate a path to implementation for the following value added objectives:

- Dissemination of data from own ship turbulence to other aircraft and ground users.
- Receive, process and deliver valid turbulence warnings to the cockpit from other equipped aircraft.
- Receive and display Flight Information Service Broadcast (FIS-B) ground-air weather products.

The architecture selected for development of an international/oceanic global weather dissemination capability is the SWIFT 64 Multiple Packet Data Service (MPDS) utilizing the Inmarsat satellite constellation. This satisfies the requirements for air to ground and ground to air dissemination of weather information and reporting of turbulence hazards.

Swift-64 packet mode currently provides only cabin services. These services are not available to the cockpit due to the level of certification and the best effort basis delivery of messages. Cockpit solutions to date have focused on implementations that address these issues through expensive hardware solutions providing separation or through use of circuit switched mode of operation that provides guaranteed message delivery of all messages.

### **Advanced Data Link Research and Development**

Advanced data link research and development is being performed within the WINCOMM project element. Due to the nature of research, validation testing will depend on the technology progress achieved. Advanced data links are included in this document for completeness and to elevate the awareness of the aviation community to these enabling technologies. Detailed information for these activities can be made available upon request and will be included in future publications and presentations.

#### **Aviation Cellular Data Link**

The objective of this effort is to leverage existing and future cellular networks and technologies for use by aviation. Existing implementations have failed to provide the required capabilities, capacity and or cost benefit possible through leveraging of the considerable investment and efforts in the development and reuse of existing public cellular networks/infrastructure. This research will develop a Proof of Concept (POC) plan for an aviation cellular capability extending the existing commercial 3G through 5G cellular networks, enabling enhanced data link capabilities and performance while minimizing recurring cost to the aviation user.

#### **Re-configurable Antenna 800 MHz - 2.6 GHz**

The objective of this effort is to design and fabricate a wideband electronically scanned reconfigurable antenna for airborne use in the 800MHz to 2.6 GHz spectrum. A key element of this program is to design and develop a Proof of Concept (POC) ASIC chip and incorporate it into a half element, whole element, and array.

In partnership with Honeywell Labs, this activity seeks to demonstrate an antenna technology that will address the issues of today's airborne cellular market and simultaneously provide for aero capacity in tomorrow's next generation wireless infrastructure.

### **Application of a VHF Radio Transceiver ASIC to VDL mode-3**

The objective of this research and development is a custom designed VHF radio ASIC in a demonstration transceiver for VDL Mode-3 data communications. The transceiver ASIC to be used was developed within the current project with the intent of creating a highly integrated radio chip for low cost avionics applications.

This effort will demonstrate a highly integrated, low cost transceiver ASIC providing data communication using VDL Mode-3 in the capacity of an electronic flight bag application.

### **Three-dimensional Weather Information Gridding and Compression**

The objective of this effort is to develop the general design, theoretical framework, and necessary models for compression algorithms. The output of this task will be an integrated compression toolkit for use in meteorological data dissemination.

## **SUMMARY**

WINCOMM has achieved early success as evidenced by the commercial offering of first generation systems providing weather information to the cockpit. WINCOMM is on track to demonstrate a clear path to implementation for second generation weather dissemination by coexistence with other traffic via current, near term, and next generation datalink technologies. Advanced data link research and development is expected to establish a foundation for development beyond the WINCOMM project scheduled end of September 2005. Unfortunately, aviation datalink limitations will keep us from realizing any far term goal of true interactive weather decision aiding or other proposed safety enhancements that rely on ground-air, air-air, or air-ground weather information dissemination. With the possible advent of security encryption overhead and traffic loads, weather information could be displaced on the current and near term links. Weather datalink research must continue and be coupled and relevant to the entire weather community. It should also focus on overcoming the two greatest aviation datalink challenges: lowering the cost and increasing the capacity.



# **WINCOMM Project Overview**

**ICNS Conference, 2004**

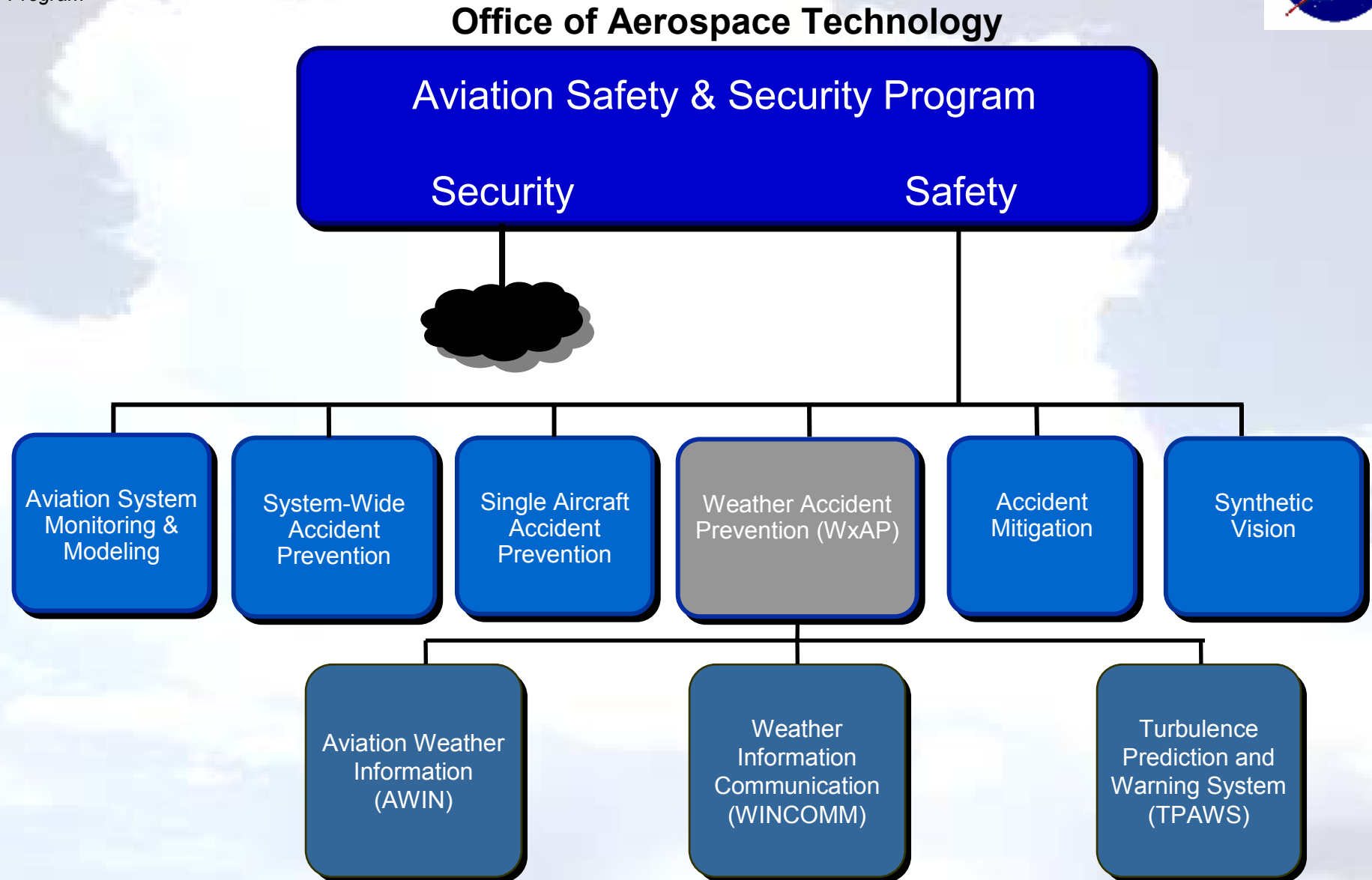
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# Organization

**WxAP: Weather Information Communications**



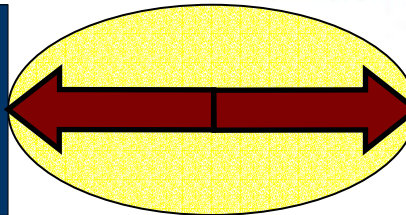
# WINCOMM Goals

**WxAP: Weather Information Communications**



**Air**

**Weather Hazard  
EPIREPS**

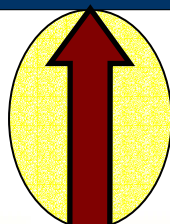


**Weather Hazard  
EPIREPS**

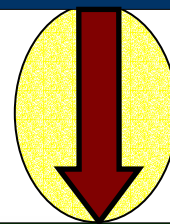
*Tactical Information*

**Air**

**Cockpit Presentation  
& Decision Aids**



**Airborne Weather  
Sensor Information**



**Ground**

**Aviation Wx  
Information**

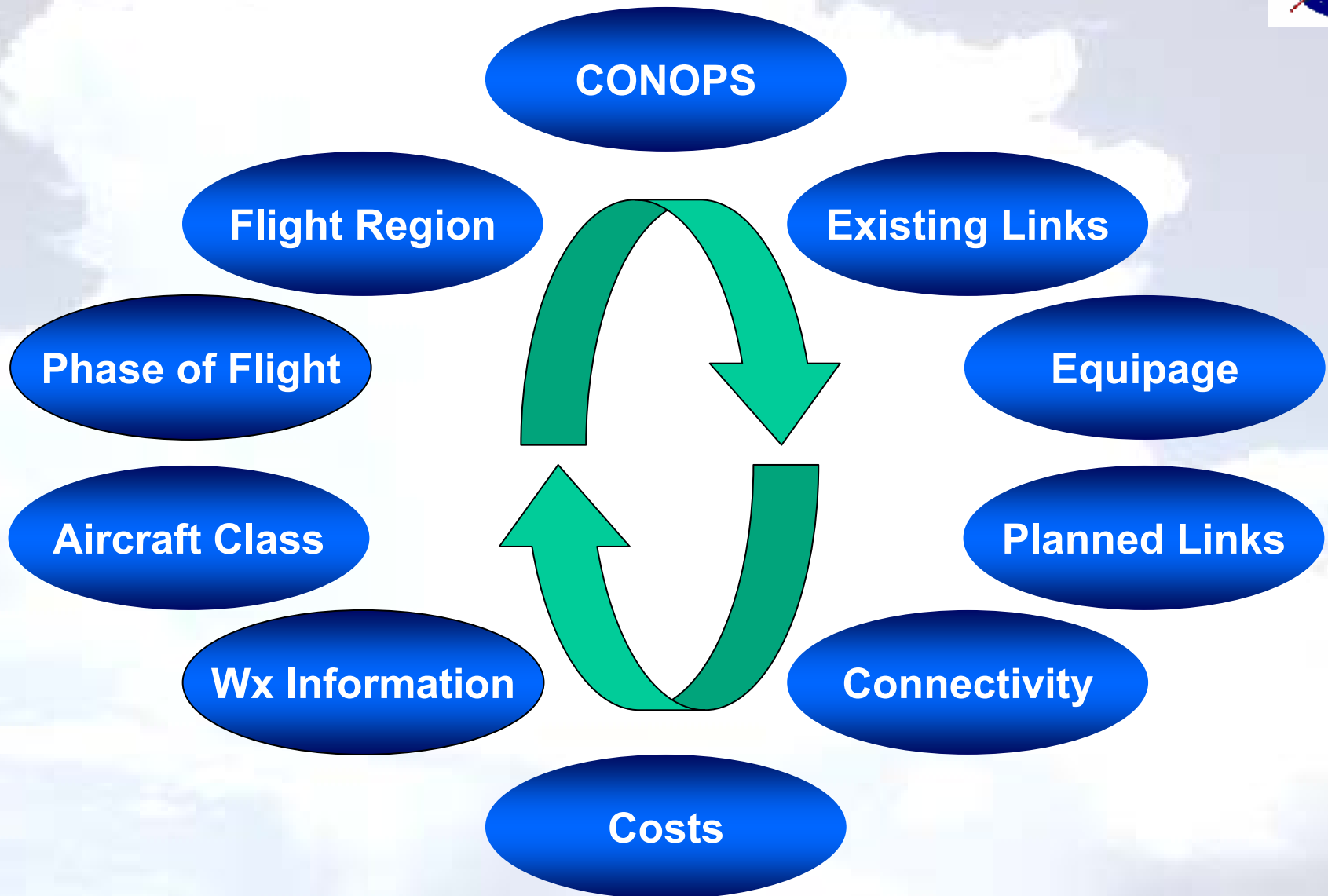
**Forecasters & Weather  
Product Developers**

*Strategic Information*

# Data Link Decision Factors

Aviation  
Safety &  
Security  
Program

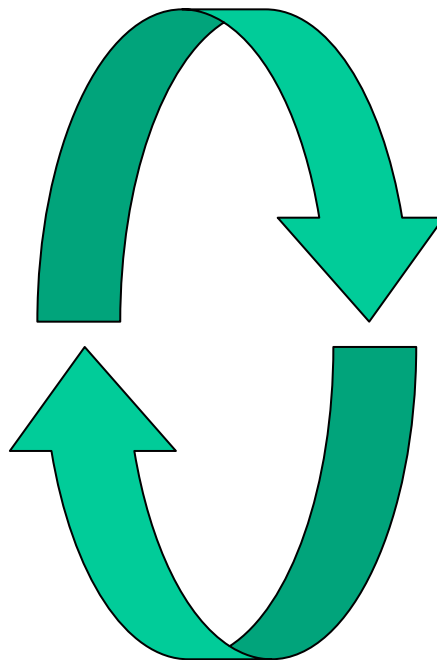
**WxAP: Weather Information Communications**



# Data Link Decision Factors

Aviation  
Safety &  
Security  
Program

**WxAP: Weather Information Communications**

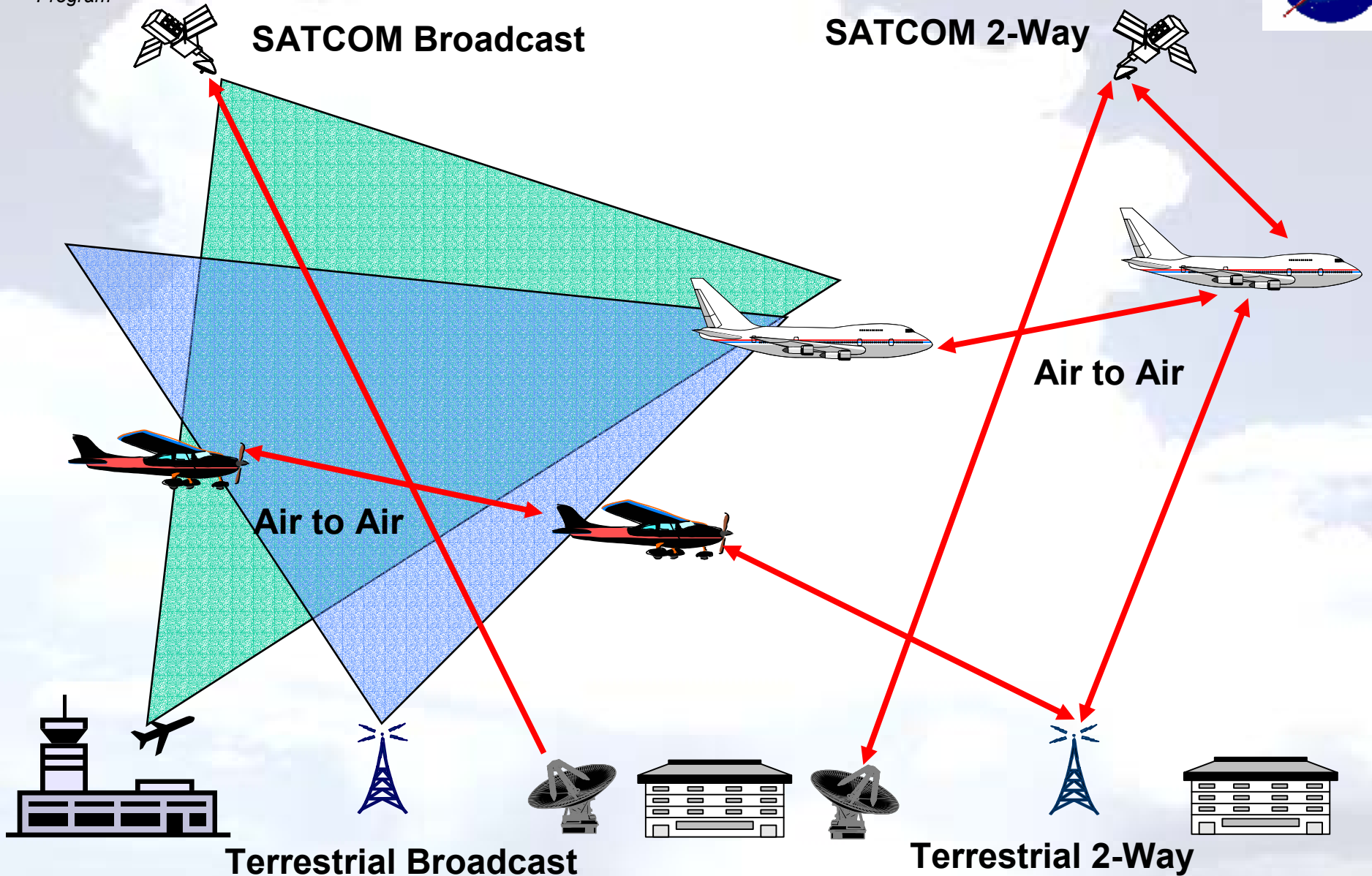


# Datalink Architectures

(weather information dissemination)

**WxAP: Weather Information Communications**

Aviation  
Safety &  
Security  
Program



# Datalink Validation Goals

**WxAP: Weather Information Communications**



- Perform Successful Transmission and Reception of Wx Information
- Show Wx Information flow does not impact “Normal” Traffic
- Demonstrate Feasibility of Operational Implementation
- Lay Foundation for Future Data Link Development

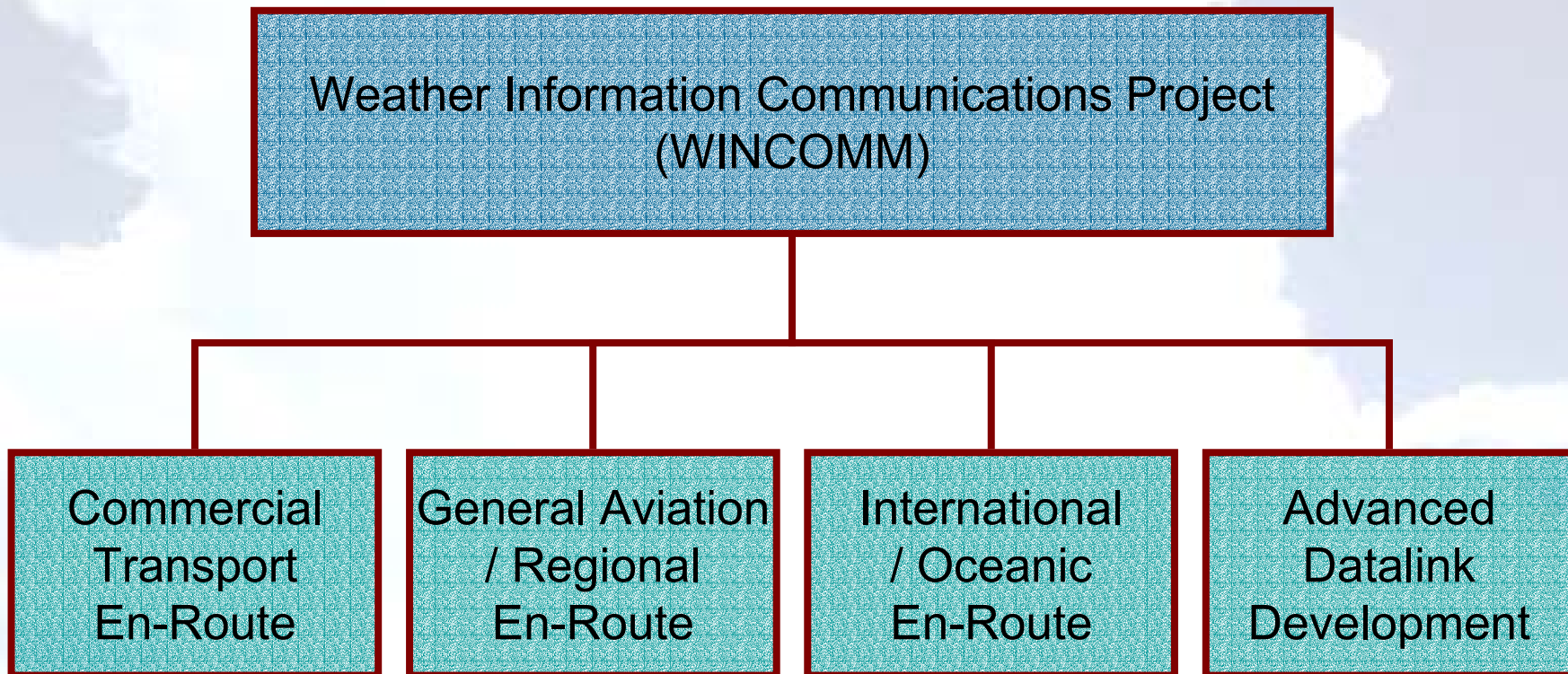
# Product Deliverables



- National Capability for Commercial Transport Weather Dissemination
- National Capability for GA/Regional Weather Dissemination
- Global Capability for Weather Dissemination
- Advanced Data Link Technology Candidates for Weather Dissemination

# WINCOMM Structure

**WxAP: Weather Information Communications**





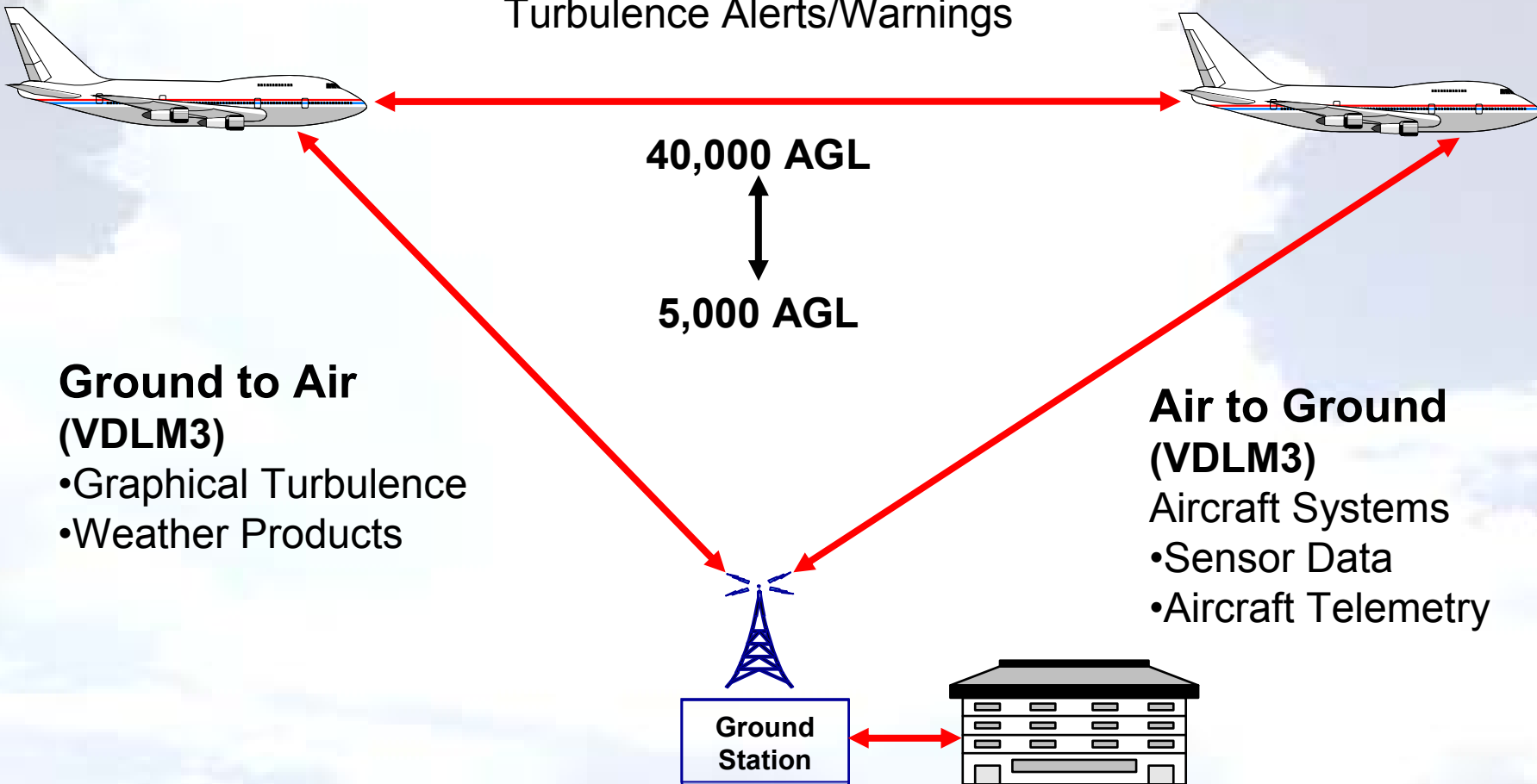
# Commercial Transport En-Route

**WxAP: Weather Information Communications**



## Air to Air (1090ES)

Turbulence Alerts/Warnings



**VDLM3 Ground Stations & Network**

# Regional/General Aviation En-Route

**WxAP: Weather Information Communications**



## Air to Air

- Atmospheric Sensor Data
- Aircraft Telemetry



40,000 AGL

5,000 AGL

## Air to Ground

- Atmospheric Sensor Data
- Aircraft Telemetry

## Ground to Air

- Graphical Wx Products
- Textual Wx Products



Ground  
Station



**FAA – UAT Ground Stations & Network**

# International/Oceanic En-Route

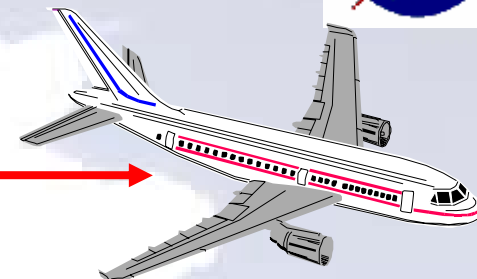
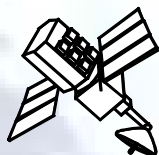
## WxAP: Weather Information Communications



### Air to Air

(Air-Ground-Air Routing)

- Turbulence Alerts/Warnings



### Air to Ground

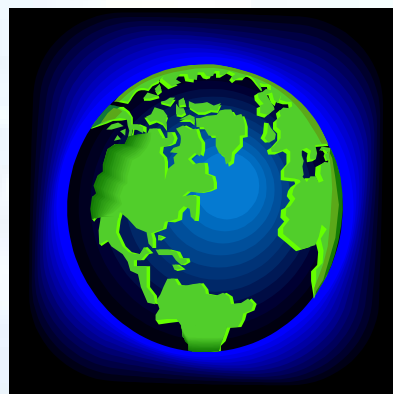
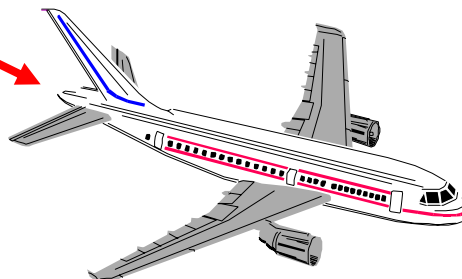
Aircraft Systems

- Sensor Data
- Aircraft Telemetry

### Ground to Air

Ground Systems

- Reports & Forecasts
- Alerts / Warnings



**SITA – Inmarsat Swift 64 &  
Network Service Provider**

National/Commercial  
Weather Providers

AOC, Dispatch, ATC

# Advanced Data Link Technologies

## WxAP: Weather Information Communications



- Aviation Cellular
  - Investigation of 4G and 5G cellular systems leading to the development of a Proof-of-Concept (POC) aviation cellular system data link solution utilizing existing public infrastructure (Briefing at WxAP Annual Review – Las Vegas, NV on June 2<sup>nd</sup> , 2004)
- Reconfigurable Antenna (Honeywell – ESCAN)
  - A Proof of Concept reconfigurable aero antenna spanning 800 MHz to 2.6 GHz will be developed
- Radio on a Chip (Honeywell – ASIC)
  - Size and cost reduction enabling compact radio designs with capability and flexibility through programmability to all VHF aviation NAV/COMM bands

# Weather Information Datalinks

WxAP: Weather Information Communications



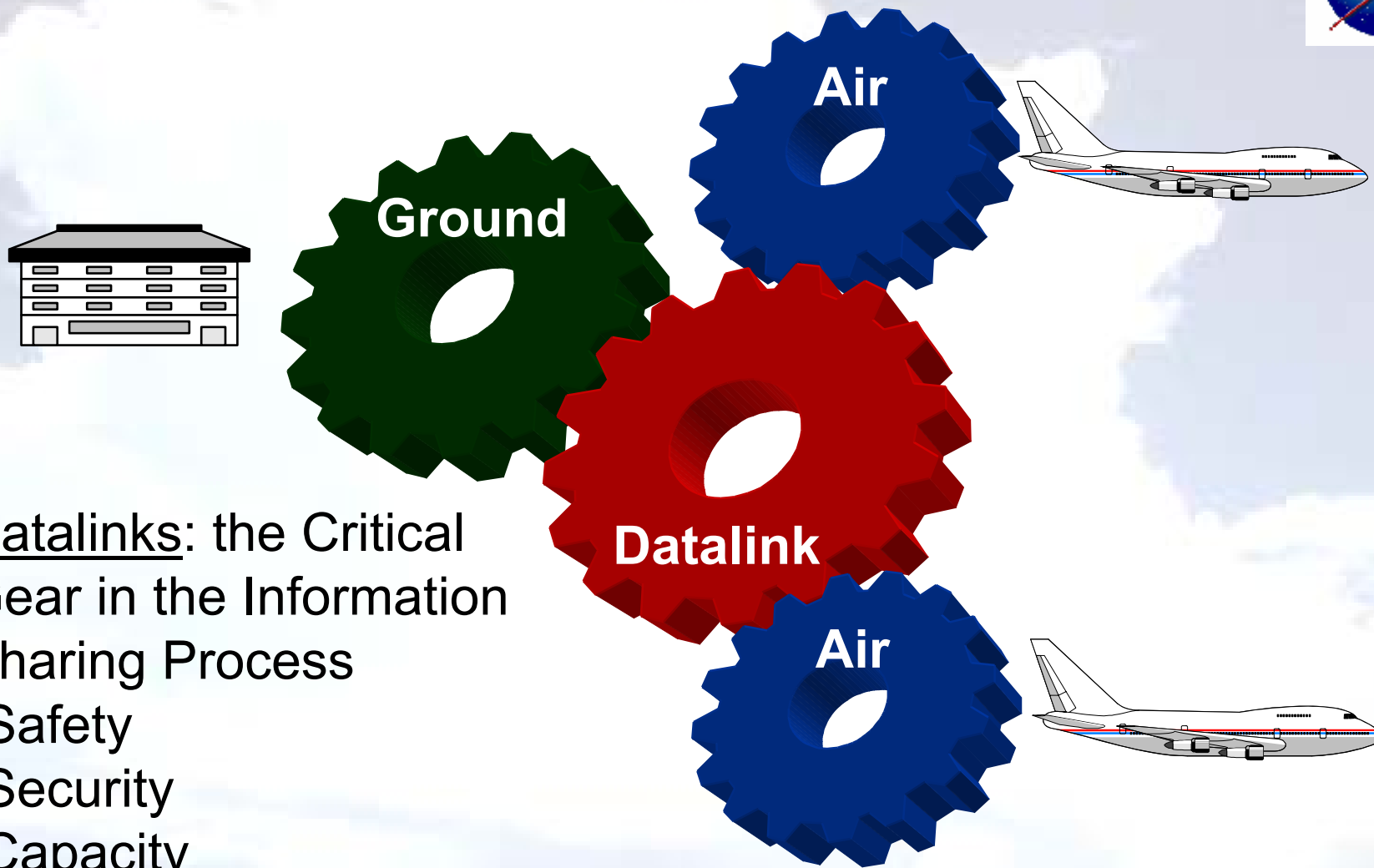
## Where we are.



## Where we need to be.

# Enabling Role of Datalinks

**WxAP: Weather Information Communications**



Datalinks: the Critical Gear in the Information Sharing Process

- Safety
- Security
- Capacity
- Efficiency

# Total System Solutions Required

**WxAP: Weather Information Communications**



**Weather Information**

**+**

**Delivery to Key Decision Makers**

- Forecasters
- Controllers
- Pilots
- Automated Control Systems

**+**

**Resultant Action**

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**Safety Benefit**

# Aviation Data Link Capacity

Aviation  
Safety &  
Security  
Program

**WxAP: Weather Information Communications**



**Limited  
Use of  
Commercial  
Spectrum**

**Graphical Wx**

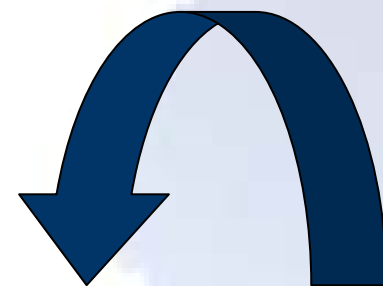
**Assigned  
FAA  
Spectrum**

**Planned Systems**

- Limited Wx
- Shared bandwidth

**Legacy Systems**

- Limited throughput
- Limited bandwidth



**Reallocation**





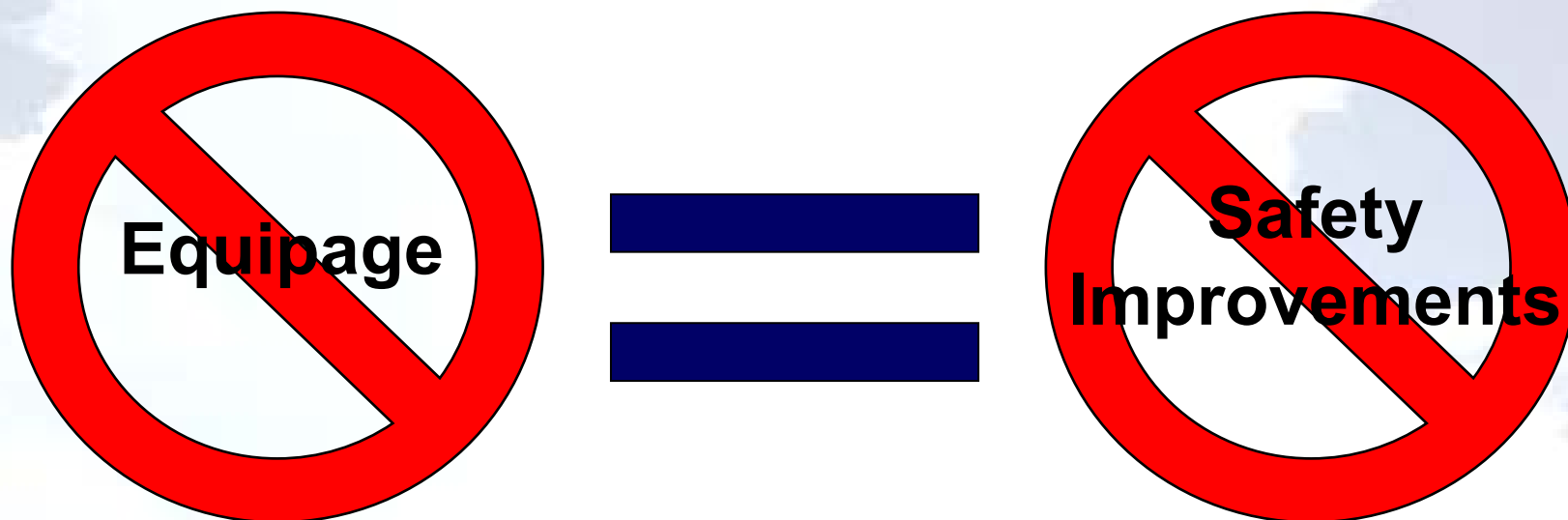
# Aviation Data Link Cost

**WxAP: Weather Information Communications**



# Aviation Data Link Cost

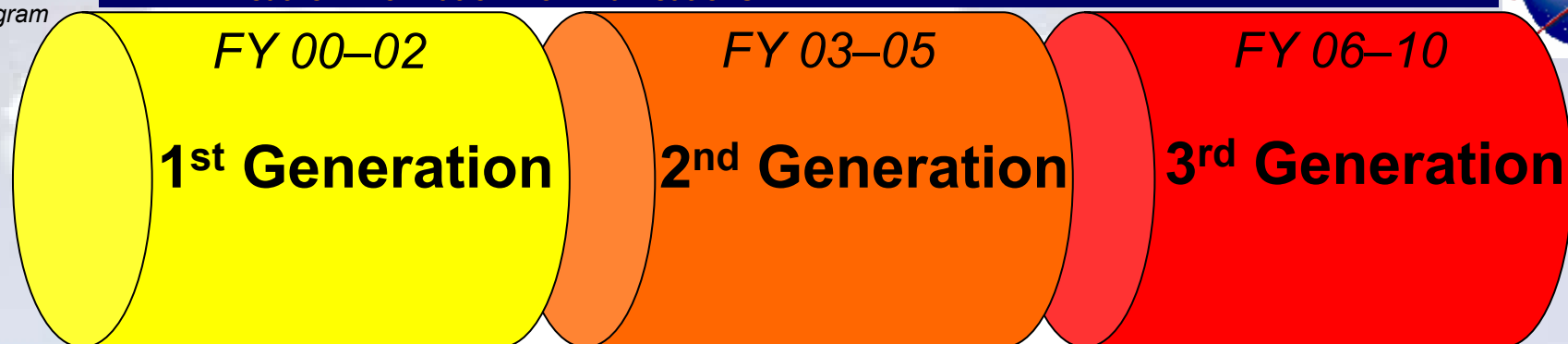
**WxAP: Weather Information Communications**



# Aviation Data Link Development



## WxAP: Weather Information Communications



- G-A Broadcast
- Private Networks
- Weather (Wx) Only
- Limited Capacity
- High Relative Cost
- GA

- FISDL (Terrestrial)
- WSI (Satcom)
- XM (Satcom DARS)

- G-A, A-G, A-A
- Private Networks
- Multi-Aviation Use
- Additional Capacity
- Increased Value
- GA & Com Transport
- EPIREPS
- A/C Wx Sensors
- Dynamic Requests

- UAT & VDLM3 (Terrestrial)
- Swift 64 (Satcom)
- 1090ES (Air-Air)

- Full Mesh Networking
- Public Infrastructure
- Information Pipeline
- Broadband
- Low Relative Cost
- All Aircraft
- Crosslinks
- Data Processing
- Routing

- Aviation Cellular
- High-Value Satcom

# About Those Great Visions...

Aviation  
Safety &  
Security  
Program

**WxAP: Weather Information Communications**



A vision without a plan  
may be  
a hallucination.